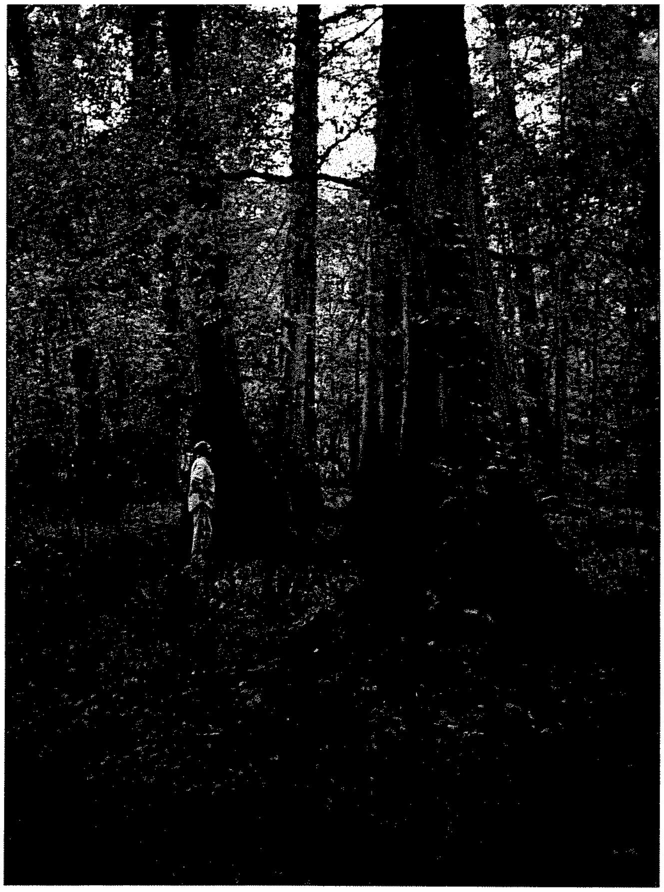

John A. Stanturf

in the Lower Mississipp Alluvial Valley

Programs to restore southern bottomland hardwood forests to the floodplains of the Mississippi have been tested on federal land and are now being applied to private holdings. The initial goals were to provide wildlife habitat and improve water quality, but other benefits—possible income from biomass and carbon credits—may make restoration cost-effective, even for small landowners. One challenge is finding the right mix of tree species that are adapted to soil saturation and root anoxia, can be planted and managed economically, and will produce a closed canopy and complex structure quickly. Bringing back the understory is another challenge.

By John A. Stanturf, Emile S. Gardiner, Paul B. Hamel, Margaret S. Devall, Theodor D. Leininger, and Melvin E. Warren Jr.

The Lower Mississippi Alluvial Valley has undergone the most widespread loss of bottomland hardwood forests in the United States. Besides the extensive loss of forest cover by clearing for agriculture, regional and local hydrologic cycles were drastically changed by flood control projects that separated the Mississippi River and its tributaries from their floodplains. Deforestation and drainage resulted in a loss of critical wildlife and fish habitat, increased sediment loads, and reduced floodwater retention. Restoring these floodplain forests is the subject of considerable interest and activity (Sharitz 1992).

The valley is one of the most endangered ecosystems in the United States (Noss et al. 1995). In separate assessments, The Nature Conservancy and Defenders of Wildlife identified the South as having high to extreme risk for significant loss of aquatic biodiversity. The World Wildlife Fund regards sustained conservation of native fishes, freshwater mussels, and crayfishes in the region as vital to maintaining a significant proportion of the freshwater fauna of the United States. Partners in Flight targeted bottomland systems across the South as the highest-priority habitats for breeding populations of neotropical migratory birds as well as staging habitats for their migration.

The US Environmental Protection Agency (EPA) has identified the Yazoo-Mississippi basin as an area of significant concern for surface and ground water quality. Although surface water runoff in the basin contributes only 20 percent of the nitrate loading implicated in the expansion of the hypoxic zone in the Gulf of Mexico, the agency is expected to focus significant resources on the basin to improve water quality. Policy alternatives under consideration include reducing nitrogen use by 20 to 40 percent and converting agricultural land to forests to restore and enhance natural denitrification processes (US

***Above:* Natural bottomland hardwood stands such as this one in Issaquena County, Mississippi, are the target for restoration.**

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EPA 1999). In response to these concerns for wildlife habitat and water quality protection, the valley has been targeted for the most extensive forest restoration effort in the United States.

Historical Background

The Lower Mississippi Alluvial Valley covers more than 24 million acres in parts of seven states, extending from southern Illinois to the Gulf of Mexico *(fig. 1)*. The valley once supported the largest expanse of forested wetlands in the United States. Rich alluvial soils received periodic sediment additions from the world's third-largest river and supported highly productive ecosystems (Putnam et al. 1960). The forests of the region are rich in species and contain as many as 70 commercial tree species (Putnam et al. 1960). Soils and drainage are variable across the floodplain, and several site types can be recognized (Hodges 1997). Hydroperiod differences (depth, duration, frequency, and season of inundation) drive stand productivity and lead to variability in structure and species composition.

Common estimates of the extent of bottomland hardwoods in the valley before European contact are 21 million to 25 million acres (The Nature Conservancy 1992), although actual forest cover may have been less because of agricultural use by Native Americans (Hamel and Buckner 1998). Fully 96 percent of subsequent loss of bottomland hardwood forests in the valley has been caused by conversion to agriculture (MacDonald et al. 1979; US Department of the Interior 1988). At the time of European colonization, wetlands were considered useful only after they were drained. The Swamp Land Acts of 1849–1850 granted federally owned swamplands to the states to be reclaimed and disposed of. Between the early 1800s and 1935, about half of the original forests were cleared *(fig. 2)*. Searching for fertile farmland, 19th century settlers cleared forests, starting from the highest and best-drained sites. Flood control projects in the 20th century straightened and deepened rivers, drained swamps, and encouraged forest clearing on lower, wetter sites. Rising world soybean prices brought a surge in forest clearing for agriculture in the 1960s and 1970s (Sternitzke 1976). The net economic return on farmland was reported to be twice as high as on forest. By the 1980s less than 20 percent of the 18th century forested wetlands remained. Since the passage of "Swampbuster" provisions in the 1985 Farm Bill, clearing of forested wetlands for agriculture has declined (Shepard et al. 1998).

The remaining 5 million acres of bottomland hardwood forests in the valley are mostly (more than 95 percent) in Louisiana, Mississippi, and Arkansas (The Nature Conservancy 1992). The largest contiguous block of bottomland forests is in the Atchafalaya Basin of Louisiana, which accounts for 31 percent of the total in the region (The Nature Conservancy 1992). A considerable portion of the remainder is *batture*—the land between the mainline levees of the Mississippi River that is subject to seasonal inundation.

Current Restoration Efforts

Restoration in the valley is driven primarily by actions on federal land and by federal incentive programs, although states have their projects on public land (Savage et al. 1989; Newling 1990). The US Fish and Wildlife Service, for example, began an aggressive afforestation program in the valley in 1987 (Haynes et al. 1995), on both refuge land and in partnership with adjacent private landowners. Current

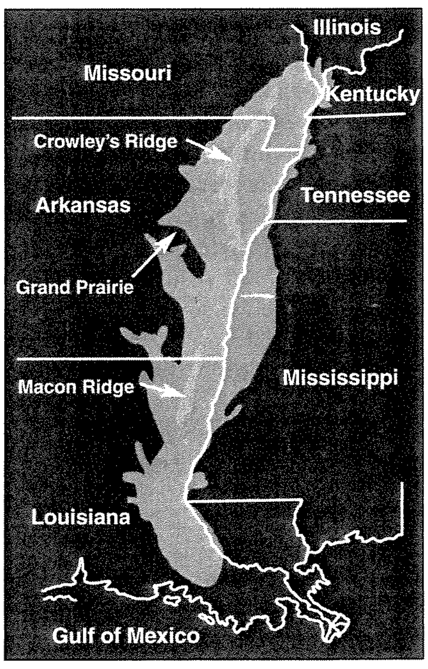


Figure 1. **The Lower Mississippi Alluvial Valley stretches from Cairo, Illinois, to the Gulf of Mexico. Crowley's Ridge and Macon Ridge are upland remnants of pre-Holocene topography. Although not bottomlands, these areas include species typical of bottomlands as well as uplands.**

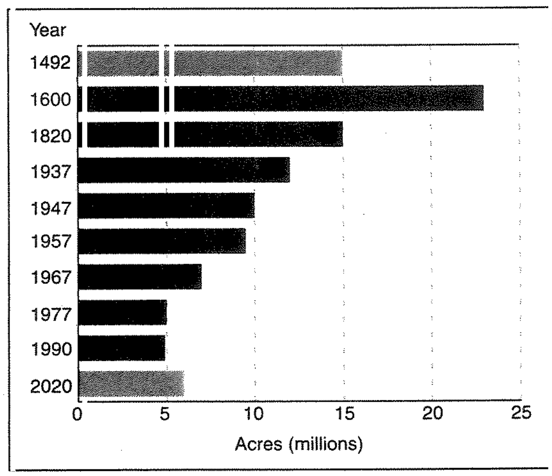


Figure 2. **Extent of bottomland hardwood forests in the Lower Mississippi Alluvial Valley from pre-European contact (1492) to modern times (1990), with projections to 2020. Our estimate of forest cover before European contact assumes that Native American agriculture was at least as extensive as early colonial agriculture around 1820. This is probably an underestimate (Hamel and Buckner 1998). Our prediction of the area to be restored by 2020 is 1 million acres, roughly double the amount planned through 2005 but half the target amount recently announced by the Lower Mississippi Joint Venture of Partners in Flight. SOURCES: MacDonald et al. 1979; The Nature Conservancy 1992.**

Table 1. Planned restoration by federal and state agencies in the Lower Mississippi Alluvial Valley.

Program	Agency	Area (acres)[1] 1995	Planned to 2005	Total
Wildlife refuges	US Fish and Wildlife Service	12,780	24,710	37,490
Wetland mitigation	Army Corps of Engineers	5,000	23,970	28,970
State agencies	Mississippi, Louisiana, Arkansas	33,360	100,075	133,435
Wetlands Reserve Program	Natural Resources Conservation Service	130,963	118,000	248,963
Total		182,103	266,755	448,858

[1] *Estimates furnished by participants at the workshop "Artificial Regeneration of Bottomland Hardwoods: Reforestation/Restoration Research Needs," May 11–12, 1995, Stoneville, Mississippi.*

plans for restoration on public and private land suggest that as many as 500,000 acres could be restored in the valley over the next decade *(table 1).*

The Army Corps of Engineers must mitigate forested wetland losses caused by construction projects, generally to control flooding. Often these mitigation lands are turned over to state wildlife agencies to manage. Many acres cleared for soybeans are subject to late spring and early summer flooding and remain uneconomical for cropping. This land is now being restored to forests under the Conservation Reserve Program and the Wetlands Reserve Program, both administered by the Natural Resources Conservation Service (Stanturf et al. 1998). Other USDA programs that could foster tree planting on small acreages include the Environmental Quality Incentives Program, the Wildlife Habitat Improvement Program, and several cost-share practices to establish riparian buffers.

The dominant goal of all restoration programs in the valley, whether on public or private land, has been to create wildlife habitat and improve or protect surface water quality (King and Keeland 1999). In practice, this means afforestation of small areas (usually no more than 300 acres) within a matrix of active agriculture. Although we know how to afforest many sites (Stanturf et al. 1998), recent experience with the Wetlands Reserve Program in Mississippi illustrates the difficulty of applying this knowledge broadly (Stanturf et al., in press).

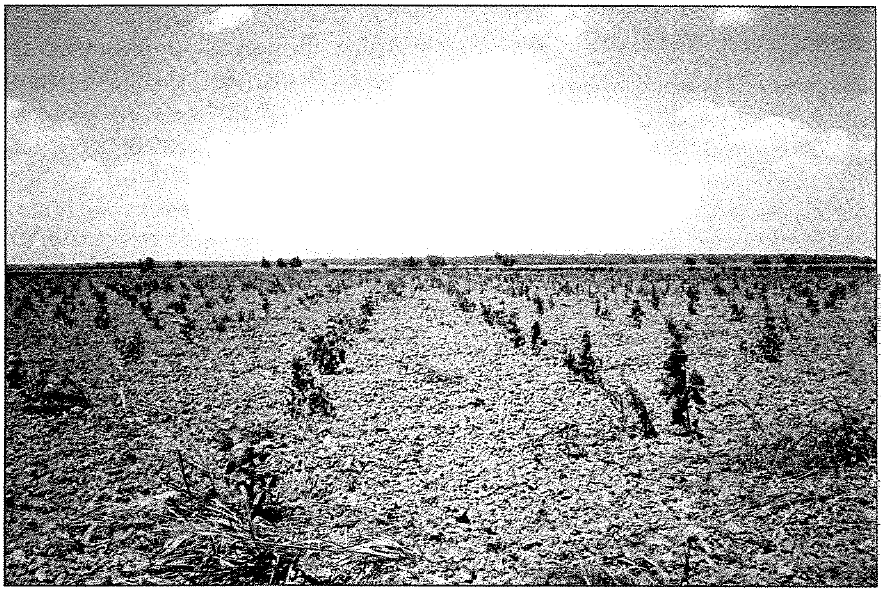
Site-Specific Techniques

Afforestation is a process, and something can go wrong at any of several steps. The most critical step is properly matching species to site, particularly to hydroperiod. Few species can tolerate continuous flooding. Even those few that can withstand extended soil saturation and root anoxia cannot tolerate submersion of all their leaves. Most flooding-tolerant species can be planted on drier sites but not the reverse (Stanturf et al. 1998). Soil physical conditions, root aeration, nutrient availability, and moisture availability are other important site factors. On former cropland, for example, traffic pans (compacted soil layers caused by traffic of farm machinery) at 8 to 12 inches in depth will limit root penetration. Ripping before planting or sowing is necessary to shatter these pans.

Seed handling is a challenge to direct-seeding efforts. Acorns must be collected between October and February. Acorns of the red oak group can tolerate cold storage for up to five years, although storage beyond two years is not advised. We suspect, however, that respiration losses during extended storage result in less vigorous seedlings. White oaks cannot be stored more than four months. The window for direct seeding (November through June) is longer than for planting seedlings (January to March), depending on flooding and soil moisture. Acorns are float tested before sowing; viable acorns of most oaks sink in water. Seed is stored in sealed polyethylene bags at 35° to 40° F. Acorns can be sown by hand or machine. Planting depth is 2 inches to 6 inches. Better survival usually results when acorns are sown at 2 to 3 inches, but deeper sowing is recommended if there are many rodents or the soil surface dries out completely.

Advantages of bareroot seedlings include the greater number of species available and the wider range of site conditions that can be tolerated. Because of higher survival rates of seedlings, the probability of obtaining an adequately stocked stand is higher, but the disadvantage is higher cost (see "Costs of Restoration," p. 14). Suitable bareroot hardwood seedlings are larger than typical pine seedlings planted in the South. The recommended size is 18 inches top length with a root collar diameter of at least 3/8 inch. Root systems must be well developed with several lateral roots. Root systems can be pruned somewhat to make planting easier, but often roots are severely pruned by crews to get the seedlings into planting holes that are too small anyway. Bareroot seedlings survive best if dormant when planted into moist soil. Subfreezing temperatures at time of planting cause root death and low survival. Seedlings also need to be protected from high temperatures on sunny days. Too often seedlings are transported to planting sites or stored in the field without protection from desiccation, resulting in low survival.

If good-quality seedlings are planted properly and well cared for before planting, establishment success will be high (around 60 percent for Nuttall oak, less for other oaks). Survival of direct-seeded oaks is lower, typically 15 to 30 percent (King and Keeland 1999). Nevertheless, natural factors beyond our control—late-spring flooding that extends into summer, a droughty spring after planting, and deer and small mammal depredation—can cause failure. In addition to depth and duration of flooding, temperature and oxygen content of the water can be important: Warm, stagnant water is more harmful than cool, flowing water. Adequate soil moisture after planting is critical to survival; planting should be suspended if stored moisture is marginal and low rainfall is predicted. Winter is wetter



John A. Stanturf

The most intensive operational restoration technique is to interplant a nurse crop of a fast-growing species with a slower-growing species. The first step is to establish the fast-growing species, such as this eastern cottonwood planted on 12-by-12-foot spacing, four months old.

Emile S. Gardiner

The second step is to interplant the slower-growing species. The cottonwood nurse crop, shown in the background, is five years old. Nuttall oaks were planted three years ago; the seedling shown above is now 7 feet tall.

than summer in much of the valley. Drought conditions are frequent on clay soils in mid to late summer, especially the shrink-swell clays common to slackwater deposits. Careful site preparation and judicious selection of species to plant can avoid exposing the roots of seedlings. Herbivory by deer, beaver, nutria, rabbits, and small mammals is common, and tree species differ in their tolerance to top clipping. Cottonwood plantations can be devastated by deer, and woven-wire fencing may be needed. Oaks, on the other hand, resprout readily, and protection may not be cost-effective. Rapid early height growth for all species is a key to overcoming flooding and herbivory problems, and it can be achieved by planting very tall (6-foot) seedlings, aggressively controlling competing vegetation for one to three growing seasons, using tree shelters, or combining these methods. The cost effectiveness of the methods has not been tested under operational conditions.

Restoration on public land in the valley follows an extensive strategy of low-cost planting or direct seeding of heavy-seeded species of value to wildlife, such as oaks. These restoration efforts rely on native species, planted mostly in single-species blocks within plantations containing three or more species. Choice of species is guided by tolerance to flooding and soil characteristics. Hard-mast producers, such as the oaks and sweet pecan, are favored for their wildlife value and because they are the most difficult to obtain by natural processes. Oaks are planted on wide spacing (12 feet by 12 feet) as 1-0 bareroot seedlings or direct seeded as acorns on 3-by-12-foot spacing to account for lower survival. Wind and water are relied on to disperse light-seeded species, such as ash, elm, sycamore, sweetgum, and maple (Stanturf et al. 1998). The light-seeded species are needed for biodiversity and stocking and to create forested conditions (Haynes et al. 1995).

The strategy that predominates on public land has shaped the federal programs aimed at private land. The appropriateness of this strategy for private land has been questioned from several perspectives (Stanturf et al., in press).

First, wind and water dispersal of light-seeded species to these small, isolated tracts is reliable only when natural seed sources are within 100 yards (Allen 1990, 1997). Failure to fill between the planted oaks means incomplete site occupancy by trees, lower species richness, and longer time to reach structural diversity.

Second, many wildlife species at risk require forests of complex structure. Extensive plantings, even if fully successful, require 60 years or more to attain a desirable structure (King and Keeland 1999; Twedt et al. 1999).

Third, the stocking that results from successful restoration under federal cost-share programs (i.e., 125 stems per acre at age 3) will not be sufficient to support commercial timber production. The lack of merchantable volume in these understocked stands will not only constrain timber management but also limit stand manipulation for wildlife habitat, aesthetics, or forest health.

Finally, the ability to sequester carbon will be significantly lower. Interest is increasing in afforestation to obtain carbon credits under the Kyoto Protocol, and the critical period for credits is between 2008 and 2012—very early in the life of stands planted now.

More-intensive strategies for quickly establishing closed-canopy forests are available, albeit at higher initial costs than the extensive plantings. For example, a manager can establish a closed-canopy forest 30 feet or taller in three years by using such fast-growing native species as eastern cottonwood. One or two years after planting, this cottonwood nurse crop is established, and slower-growing oaks can be planted between every other row. Later, the man-

Costs of Restoration

Estimates of the direct costs of four restoration methods are shown in *table 2*. Direct seeding of acorns has fallen out of favor because of low success rates in operational plantings; nevertheless, it can be successful and offers substantially lower costs. The estimated cost of planting 1-0 bareroot seedlings is given at two levels: the low intensity applied on public land, aimed at producing 125 stems per acre (spa) of hardmast species at age 3; and a higher-intensity level recommended for multiple outputs including timber production. Interplanting two species is the highest-intensity practice and costs the most to establish, but it produces vertical structure in two to three years and recovers functions faster than the other practices. When cottonwood is used, it can provide the landowner with financial returns in 10 years.

Table 2. Typical direct costs per acre for afforestation of bottomland hardwoods in the Lower Mississippi Alluvial Valley.

	Direct-seeded oaks[1]	Low-intensity bareroot seedlings[2]	High-intensity bareroot seedlings[3]	Interplanted cottonwood and oak[4]
Site preparation				
Disking	$ 16	$ 16	$ 16	$ 16
Preemergent herbicide			13	13
Rip and mark				15
Fertilize				15
Planting				
Material	25	75	75	60
Planting	35	35	35	20
Year 2 planting oak seedlings				56
Weed control				
Chemical			11	11
Mechanical			10	20
Insecticide				9
Year 2 weed control			10	10
Total	$ 76	$126	$170	$245

[1]*Suitable oaks are direct-seeded at 12-by-3-foot spacing (1,211 stems per acre, spa) with target survival of 125 spa at age 3.*
[2]*Low-intensity planting is typical of national wildlife refuges and the Wetlands Reserve Program; trees are planted at 12-by-12-foot spacing or wider (302 spa) with a target of 125 stems per acre surviving at age 3.*
[3]*High-intensity planting is needed for timber production: 12-by-12-foot planting (302 spa) and a target of 250 spa at age 3; survival is assumed to be double that of low-intensity planting because of weed control.*
[4]*Cottonwood is planted at 12-by-12-foot spacing (302 spa); to get a survival rate of 80 to 95 percent requires one to two years of weed control. The oak seedlings are interplanted after one or two growing seasons between every other row of cottonwood at 12-by-24-foot spacing (151 spa). Cottonwood can be coppiced to provide income from a second rotation before the oaks are released.*
Sources: Bullard et al. 1992; King and Keeland 1999; Stanturf and Portwood 1999.

Most restoration on private land is subsidized by the Conservation Reserve Program or the Wetlands Reserve Program. Subsidies vary by state, but the Wetlands Reserve Program typically pays $350 per acre for a perpetual easement within three years of signing the contract. The Conservation Reserve Program pays an annual soil rent; in 1998, rates per acre per year were $35 in Arkansas, $45 in Louisiana, and $44 in Mississippi. Reimbursement for direct restoration costs also varies by state, but generally both programs now pay about half the costs of approved practices.

ager may intervene to shape stand structure and composition. Possibilities include harvesting the cottonwood at age 10, either in winter to maximize sprout regrowth and allow a second coppice rotation of the cottonwood, or in summer to minimize cottonwood sprouting and release the oak seedlings (Schweitzer et al. 1997).

The full benefits of the interplanting technique are being investigated, but observations in operational plantings indicate that significant wildlife benefits are realized within five years (Twedt and Portwood 1997). Several thousand acres have been restored in this fashion under the Conservation Reserve Program. Recently, the Natural Resources Conservation Service has funded pilot plantings using the technique in Arkansas, Louisiana, and Mississippi.

Restoration Future

Approaches to restoration in the valley are changing. Public agencies are reappraising their emphasis on oaks. Besides evidence that widely spaced plantings are not creating the desired diversity of other hardwood species (Allen 1997), the predominance of oak in the presettlement forest is questioned (King and Keeland 1999). No doubt fewer oak seedlings, as a percentage of the total, will be planted over the next several years, but more as a result of circumstances than any shift in policy. The area planted under the Wetlands Reserve Program has increased each year, and the supply of oak seedlings has tightened. Red oak acorns are best stored only one or two years and white oak acorns only a few months without significant loss of viability. The region saw a poor mast crop in 1999, so fewer oak seedlings will be available. Although several new commercial nurseries have opened and large planting contractors develop their own supplies, agencies and landowners will have no choice but to shift to a higher percentage of nonoak species in restoration programs (see "Pondberry: Restoring the Understory").

Constraints on seedling supply are

not likely to be short-term. Vigorous seedlings of all species will continue to be in limited supply as nurseries cope with increased disease problems as a result of the imminent ban on methyl bromide, used to fumigate nursery beds. One response may be efforts to increase outplanting survival and enhance seedling vigor. By planting fewer seedlings per acre for a given target density and investing more in site preparation and postplanting weed control, operational survival could probably be doubled.

The economics of private land restoration will gain importance. Current federal programs that provide large easement payments are expensive and probably justified on wetter sites. On better sites, however, restoration might pay its own way with only cost-sharing needed to establish the forest. Landowners could derive periodic income from timber production, particularly of fast-growing species like cottonwood. Production of biofuels from cottonwood or willow will not provide the same wildlife habitat enhancement as oaks, but such early successional habitat is in short supply (Twedt et al. 1999). Annual income from hunting leases or carbon credits is more speculative but will be available for some landowners. New partnerships and programs are appearing (see "Partners in Restoration") and could extend restoration even to the highest and best sites, in direct competition with staple agricultural crops—even King Cotton.

Pondberry: Restoring the Understory

Complete restoration of forested ecosystems is the ideal, and many restorationists quickly point out that afforestation by itself is insufficient. Although our ability to restore understory plants is limited, the endangered shrub pondberry *(Lindera melissifolia)* presents an opportunity. Pondberry grows in seasonally flooded wetlands and on the edges of sinks and ponds in the Lower Mississippi Alluvial Valley. It is a stoloniferous, clonal shrub up to 6 feet in height. The species has been affected by habitat destruction and alteration, especially timber cutting, clearing of land, and drainage or flooding of wetlands. Opportunities for dispersal to new sites are very limited now because of changes in hydrology and land uses in areas surrounding pondberry populations. The species will likely decline without human intervention. Unlike most endangered plant species, which have narrow habitat requirements, pondberry has a wide ecological amplitude. Individual stems can be easily transplanted and multiply rapidly, and the chance for successful reintroduction appears high.

Partners in Restoration

Increasingly, federal agencies are entering into partnerships with private conservation organizations to implement restoration programs on public and private land in the Lower Mississippi Alluvial Valley. Recently the US Fish and Wildlife Service received $10 million from Illinova, an energy company, to restore 100,000 acres in the valley over the next five years, in return for carbon sequestration credits. Initially the funds will target federal wildlife refuges, but a program for private land is likely to develop.

The Missouri Bootheel Reforestation Demonstration Project is part of an initiative in the valley led by the Business Council for Sustainable Development–Gulf of Mexico, with partners in forest industry, the Forest Service, and economic development groups. The objective is to demonstrate that afforestation is an environmentally preferable and economically feasible alternative to growing row crops on certain ecologically sensitive lands in the Missouri Bootheel and the southern tip of Illinois. The ultimate goal of this initiative is to convert 1 million acres of economically marginal cropland throughout the Lower Mississippi Alluvial Valley to timber over the next 20 years. The demonstration effort has four components: outreach, research, finance, and economic development.

The USDA Forest Service and Ducks Unlimited are developing a broad-based partnership for watershed restoration. The mission of this collaboration is to catalyze restoration on private land by strengthening existing partnerships, building new relationships, providing a scientific foundation for restoration, and implementing restoration on private land. Restoring the Delta Watershed Restoration Project includes a five-year restoration research program to develop new techniques; establish research and demonstration sites in Arkansas, Louisiana, and Mississippi; and quantify benefits to wildlife, water quality, and carbon storage at the local scale. Using GIS, benefits will be extrapolated to the landscape scale. Simultaneously, restoration will be implemented on about 40,000 acres. The project is slated to begin in 2001.

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